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Weathering of Coal

Chemical Engineering

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WEATHERING OF COAL

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BY

NAIN DELF HAMILTON

THESIS

FOR THE

DEGREE OF MASTER OF SCIENCE

IN

CHEMICAL ENGINEERING

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1907

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UNIVERSITY OF ILLINOIS

May 31 1907.

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Nain Delf Hamilton

ENTITLED Weathering of Coal

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Master of Science

in Chemical Engineering.

S. W. Parr
Instructor in Charge.

APPROVED: S. W. Parr

HEAD OF DEPARTMENT OF Chemistry.

11911

Introduction.

For many reasons, present conditions often necessitate the storing of large quantities of coal. On account of the seasonable demand for fuel for domestic purposes, mining interests find it to their advantage to store coal during the otherwise dull season and thus maintain a uniformity in working conditions at the mines, which is in accordance with the principles of economic production, as well as prevent poor conditions and dissatisfaction among the miners. This fluctuating demand likewise affects the coal dealer who must have a supply of coal on hand to supply the market. Manufacturers are beginning to see the need of supplying themselves with fuel in case their supply be cut off by some unforeseen condition at the mines or in transportation companies. The Railway interests who, according to the Interstate Commerce Commission, used over one-fourth of the coal supply of the United States in 1905,[21] look out for their own coal supply even at the expense of other industries and are thus constantly prepared to continue their business should any contingency at the mines result in a temporary cutting off of their coal supply. The worldnaval powers, especially England and the United States, have profited by such examples of lack of coal as that of Cervera at Santiago, and are now storing coal near their coaling stations to be drawn upon in case of emergencies. When the fact that the steamship "Deutschland" uses 570 tons of coal daily is con-

sidered, it will be clear that great quantities of coal must be stored near the docks, on barges and in the bunkers of innumerable sea-going craft. The needs of the above mentioned interests, which are rapidly growing, the rapidly increasing supplies for municipal welfare, together with the problem of local storing of coal for the allaying of the suffering from the extreme cold of those living in districts more or less isolated from the bases of coal supplies by lack of transportation facilities, makes the question of coal storage one of great importance.

It is not surprising, therefore, to learn of the increasing number of storage plants where coal may be placed in large quantities to replenish the needs of these great industries if, from any cause or combination of circumstances, a coal famine should ensue. An example of this is the plant of the Philadelphia and Reading Coal and Iron Company at Abrams, Pa.[1] At this plant arrangements are made for eight piles of coal each containing 60,000 tons piled on the ground in the open and equipped with modern facilities for dumping and reloading. The storage plant of the New York Edison Company at Shadyside, New Jersey where 150,000 tons of coal are stored in three piles on a bed of cinders in the open,[2] that of the Lehigh Railroad at Wyoming, New York, with a capacity of 100,000 tons,[3] are but a few of the instances where our industries are resorting to outdoor storage for reserve coal supplies. This method of storing is not only the practice where large quantities of coal are to be taken care of, but there are very few power and heating plants and fuel using industries that do not find it necessary to pile more or less coal on the ground at least temporarily until

room can be made for it in the coal shed or boiler house. The practice in vogue in the coal fields, among coal dealers, and all consumers of comparatively small quantities varies greatly. In general, however, it may be said that the coal is either stored in covered iron or wooden bins with slanting bottoms to facilitate its removal or in ordinary covered bins with earth, cinder or wooden floors and is removed with the scoop. In power and heating plants the placing of the coal bins depends upon the position of the boilers and the method used for firing and transportation of the fuel to the building. The United States Navy, which uses about 250,000 tons of coal yearly has been equipped with large coal storing facilities, the compartments in the station at the New York Navy Yards having a capacity of 525 gross tons and with floor of Portland cement, roof or iron and side walls of Portland cement, sand and anthracite boiler cinders.[20] On board vessels coal is stored in whatever room there happens to be left. Aside from the prevalent method of caring for coal reserves, the method of storing coal under water is coming into prominence, but the working out of this method cannot be said to have gone farther than the experimental stage. The English Admiralty has been experimenting with submerged coal and the Western Electric Company of Chicago has recently built two bins of 4,000 and 10,000 tons respectively below the ground level. The plan is to dump the coal into the bins directly from the car and flood it with water until needed for use when a crane fitted with grab buckets will lift it to the car again.[5]

That some loss of otherwise available energy that is stored up in freshly mined coal is caused by the present modes of storing

is generally conceded. No very great amount of research upon this subject has as yet been done. Conditions as well as quality of coal vary, and hence a difference of opinion as to the amount of this loss, the reasons therefor, and means of its prevention prevails among those interested in the subject. So closely is the subject of spontaneous ignition related to the deterioration of stored coal, that investigations as to the causes and prevention of this trouble with large quantities of stored coal are includedin the following experiences, researches and theories of those who have investigated these phases of the coal question.

Historical

Reder 1866[6], found that storing coal for a year caused a deterioration in the heating value but no appreciable loss of weight.

After careful experiments, Dr. Richter in 1868[6] concluded that the weathering of coal is due to the absorption of oxygen, a part of which goes to the oxidation of carbon and hydrogen in the coal, and part is taken into the composition of the coal itself; that if the heap becomes warm, either through this process or through any other cause, the action is accelerated, but then falls off and becomes so slow that the changes effected within a year are hard to estimate; that moisture as such has no direct influence upon the process, apart from the presence of pyrites or from the coal crumbling down more rapidly when wet than when dry, and therefore more rapidly heating up. At a later date he concluded that large coal was less affected than small, not because it had less surface, but because small coal was a more active absorbent of oxygen, and therefore became more rapidly heated; that airways

in heaps would have to be very numerous in order to prevent any rise in temperature, and that the heap ought to be so constructed as not to allow air to get from the driveways into any bulk of the coal.

Haedicke in 1880 [6] assigned to pyrites the leading part in spontaneous combustion, but it will not cause this unless the temperature is allowed to rise sufficiently.

Professor Fischer of Gottingen, as a result of research work prior to 1901 [6], concludes that storage depreciation and spontaneous ignition are phenomena of oxidation; the part which is played by iron sulphide has been disputed, but the variances that have given rise to the uncertainty are due to the differences between the different sulphides of iron present in coal. Marcasite, for example, is much more weatherable than ordinary pyrites. Actual wetting is much more promotive of oxidation of the iron sulphide than heating in dry or even moist air. He also finds than many coals contain sulphur in the form of unsaturated organic compounds. He finds that those coals which rapidly absorb bromine are those which are most liable to rapid oxidation and spontaneous ignition, and as a practical test he recommends shaking a gram of the finely ground coal with 20 c.c. of a half-normal solution of bromine for five minutes. Then if the smell of bromine has not disappeared the coal may safely be put in store, if it has it should be used up as soon as possible. If the absorption of oxygen is by the unsaturated organic compounds the coal gains weight, but if absorbed by the carbon and hydrogen, this absorption causes a loss in weight due to the carbon-dioxide and water given off. Wheth-

er a coal gains weight is, therefore, dependent upon the composition of the coal. Covering wet slack coal with other coal is apt to produce spontaneous ignition; the danger here appears to arise from the sulphide of iron rather than from the organic compounds. He regards ventilation of the coal heap with suspicion, not because the idea is in itself wrong, but because it is not practicable to ventilate the whole heap efficiently. He says the coal should be stored dry and kept dry under cover and in layers not too deep.

Durand 1883[16], explains the spontaneous ignition of coal in the pit by the presence of pyrites, which becoming heated gives rise to combustion. Fayol maintains that the main cause of spontaneous ignition is the absorption of oxygen accelerated by fine division and heat.

Jackson 1905[11], says that it is well known that coal on exposure to the weather, does lose some of its volatile constituents, even under ordinary conditions.

In a paper read before the German Gas Association in 1900,[6] Herr Sohren said that it is no longer possible for many reasons, to work gas works with a supply of coal renewed from month to month; and that all questions affecting storage have therefore a continuously increasing importance.. Undoubtedly there is a greater or less depreciation in quality of coal kept in store; and the causes of this have attracted a great deal of attention, though, on the whole, it is surprising to find to how great an extent the study of the chemistry of coal has been neglected. Questions of this nature first assumed importance in connection with the spontaneous ignition of coal in ships; in 1874, out of a list of 4,485 coal

laden ships no fewer than 60 went on fire.

Lieutenant-Commander J. R. Edwards of the United States Navy, 1901[4], said that experience has taught the dealers at Trinity Building, New York, that every time coal is handled there is a depreciation of five per cent. in value due to the loss in weight by the breaking up of the coal and the volatilization of the hydrocarbons. It is a fact that the best coal does not disintegrate and powder so quickly as the poorer quality, for the hydrocarbons make it less friable.

Groves and Thorp, pp. 82-83 Chemical Technology[7], state that gases occluded in the crevices or cavities of coal escape during mining and continue to do so after storing and disastrous explosions on vessels carrying coal cargoes have resulted.

An analysis of these exuded gases reveals their inflammable nature and throw light on the action of the air on coal which is exposed to it for any length of time. They term this latter action "weathering", and state that it consists mainly in the combination of the carbon and hydrogen of the coal with the oxygen of the air, carbonic acid and water resulting. Pyrites, if present, is also oxidized and when present in large quantities causes the coal to disintegrate and oftentimes to be nearly useless. Calorific value is diminished by this exposure to the air and in some cases there is known to be fifty per cent. loss. Oxidation may proceed so far that elevation in temperature occurs and spontaneous combustion results. Oxidation of pyrites, especially in the presence of moisture, greatly adds to the danger. To avoid the small coal, the packing of coal in lumps in vessels is proposed, but the move-

ment of the ship would break up the coal and only delay the action. Also suggest sealing up the coal hermetically but this would be impossible. T. Rowan suggested the heating of coal to drive off the moisture before storing on board. The plan is a poor one on account of the cost and the oxidation which the heating would promote.

A. D. Parker, General Auditor, Colorado Southern 1902,[8] states that the loss in transporting coal has never been definitely determined. It consists of shrinkage, droppings, stealing, etc. Evaporation or shrinkage is inevitable. It is greater with softer coals and diminishes with density. Where coal is placed in storage shrinkage becomes a very large item.

Mr. Stelkins, in his report before the International Navigation Congress 1902,[4] stated that spontaneous ignition increases with the height to wich coals are heaped. Stacks should not be made higher than five meters. Warm rains during and after stacking, and strong compression by dumping down coals from a great height all add to the danger of ignition. According to past experiences, gas flaming pit mouth coals ignite most readily, fat pit mouth slack, lean slack and nut less readily, and lump coals only very seldom. When the amount of slack increases and the amount of stony material increases the height to which it is safe to store coal decreases. Mr. Zörner in this same convention claimed that lightering coal renders it more liable to Physical and Chemical attacks and more difficult to use as fuel. Rischowski ascertained a loss of three per cent. in calorific power of fresh slack coal after a storage of four months.

Engineering News, July 21, 1904[20]. In the New York Navy Yard

space is not an item, but spontaneous combustion is an important one, hence the coal depth is limited to 18-25 feet, and the walls surrounding the bins are fire-proof. In each bin which contains 525 tons of coal are placed two four inch pipes each containing thermostats electrically connected to an annunciator. These thermostat containing tubes are arranged so as to be moved completely through the coal. A method of removing the coal from the bottom of the bins is provided and this may be done and the portion removed and redistributed over the top to prevent fire.

F. M. Griswold of the Home Insurance Company 1904[20]. Spontaneous ignition is more marked in free burning or so-called "high steaming coals" including "gas coal". These coals usually contain a large per cent. of volatile constituents with a modicum of oxygen and the tendency to ignition is greater when lignites or sulphur in any form, and especially when iron pyrites is present. Dirty or mine run coals, when fine particles sift to the bottom and are compressed are dangerous. No satisfactory explanation of spontaneous ignition of bituminous coal has been made. The best authorities say it is due to chemical changes in the substance of the coal resulting from the absorptive powers of carbon increasing with the rise of temperature. Rise in temperature may be due to the chemical action due to slow oxidation or mechanical force of pressure and these conditions stimulated by pyrites or moisture. Some claim that over 2-1/2 per cent. of sulphur in the form of pyrites is dangerous. Various tests have been proposed to determine the liability of a coal to heat, such as the gain in weight in sample at 250° Fahr. and absorption of bromine, but these tests are not

valuable as it is difficult to tell how much oxygen the coal has already absorbed. He recommends that no wood be used in the construction of bins, that all iron work be covered with concrete, no steam pipes or flues in bins, a good circulation of air about sides and under bins, coal not above a depth of twelve feet, roof on bins, permanent pipes, if possible, containing thermostats through bin, and when 140° Fahr. is reached something should be done to stop rise in temperature.

Professor Vivian B. Lewis, Royal Naval College 1906[11]. Increase of mass leads to spontaneous combustion. Substances, especially those of vegetable origin, undergo slow oxidation at temperatures below ignition point. A certain increment of temperature is generally needed to start slow combustion, but when once the required rise takes place the operation commences and the ignition point is reached. Initial increase may be brought about in several ways: first, by physical action, as in the absorption of a large volume of gas and its compression within the pores of the substance; second, by a rise in atmospheric temperature; third, by a direct chemical reaction taking place at ordinary temperature and by the action of ferments on most organic matter. To the first class belongs the spontaneous ignition of a mass of powdered charcoal or lamp-black. Coal may be considered as consisting of carbon, hydrocarbons and inorganic constituents. Among the latter is iron pyrites. If these pyrites are piled in heaps, exposed to air and moisture, they rapidly heat and often inflame, owing to the oxidizing action of the air.and moisture upon the sulphur, and many think this is the cuase of spontaneous ignition. Careful study of phe-

nomena occurring during the heating of coal leads to the conviction that pyrites plays but a subsidiary part, and that is really the absorption of oxygen by the freshly won coal and the activity of the condensed gas in contact with the hydrocarbons of the coal that are the active factors in causing ignition. In the coal seam, coal pores are filled with methane or methane and carbon-dioxide. When coal is brought to the surface it exudes these gases and absorbs oxygen from the air. As long as the pieces are fairly large no heat is perceptible, but as coal becomes broken up, the surface increases and the absorption of oxygen is increased. Mere absorption of oxygen is insufficient to bring about serious consequences unless there is an initial rise in temperature. Hence, spontaneous ignition is found to occur when cargoes go through the tropics and when coal is stored close to boilers, steam-pipes, fire boxes, etc. Water aids the action of the occluded oxygen, and hence rain when coal is being loaded causes danger. Ventilation of coal on land may aid in preventing ignition, but this is hard to obtain on shipboard. Steam and water have failed to successfully quench fires. Sulphur-dioxide and carbon-dioxide will extinguish the fires but not cool the coal and prevent another fire. Suggests that liquid carbon-dioxide be placed in vessels whose nozzles are made of an alloy of lead, tin, bismuth and cadmium and melts at 93° C. and these vessels be placed in the coal bins. When the melting point of the alloy is reached the carbon-dioxide will quench the fire, cool the coal, be absorbed by the coal and prevent any further occlusion of oxygen.

A. E. Dixon 1906. Bituminous and semi-bituminous coals

are losing constantly in heating value. Gas is being liberated and the loss is greater in a warm climate and in warm weather. Bituminous coals undergo a slacking process, the lumps shrink and the percentage of dust increases. In winter the contained moisture freezes and breaks up lump coal. Spontaneous ignition occurs with bituminous, friable coal, and particularly with those grades containing brasses or iron pyrites, and when the coal is damp the trouble is augmented. The cause is probably due to the absorption of oxygen by carbonaceous material, just as is the case with oily cotton waste.

H. R. King 1906[5], claims that the carefully executed tests in Europe show that 30 per cent. of the fuel value of coal is lost in six weeks when coal is stored out of doors.

The Naval and Military Record of England[10] gives an instance of where the British ship, Spartiate, required 3,000 tons of coal stored in England in running to China and 4,400 tons of practically the same grade of coal that had been stored in China for the return trip.

Lord Charles Beresford 1903[12], stated that in his experience a vessel would have to consume more than twice the normal amount of coal per indicated horse-power, if the coal had been kept too long in store.

Churchyard, locomotive engineer of the Great Western Railway, England 1902[12], stated that judging from his personal experience and observation, the loss of stacked coal in steam raising power is about 10 per cent.

Mines and Minerals, 1901[18]. For manyyears there has been in vogue in New South Wales a custom of taking certain percentages

from the gross weight of coal cargoes, giving bills for the net quantity only. The idea was to allow for the wastage which it was thought took place in various ways between the time of weighing at port and delivery. The practice has been to deduct two per cent. from the gross weight of foreign exportations and one per cent. from that intended for intercolonial markets. Due to the dissatisfaction, on January 1, 1901, the deduction on foreign cargoes was reduced to one per cent. and no allowance is now made on intercolonial cargoes.

Journal of the Society of Chemical Industry 1894[19]. Various kinds of coal were exposed freely to the air, immersed in water both running and stagnant for twelve months, and changes produced in their composition and heat of combustion determined. The three kinds of coal used were, (1) from Frankenholz mine, Bavaria;(2) from Drocourt; (3) from Arsean, Prele.

These coals were broken and passed through 10 m.m. mesh but not 3 m.m. mesh. Measurements show that exposure to the air or immersion in water for the time indicated, produces changes in the composition and heat of combustion which are so small as to be neglected for practical purposes.

John Macaulay, General Manager of the Alexandra Docks and Railway, Newport, Mon., 1903[12], estimates that in case of coal stacked by the Mersey Railway the loss was between 10 and 12 per cent, and if kept over a year the greatest loss is in the first twelve months. In hot climates the loss is greater. Mr. Macaulay who has also done considerable research upon the storage of steam coal under water says that the mud men along the Usk River gathered parts of submerged cargoes and found that the coal gave a hotter fire than did

fresh coal. In North Pembrokeshire they refloated a vessel which had been sunken for two years and found that the coal was the best they had ever used. Mr. Macaulay's own experiments include the placing of a sample of the best Monmouthshire coal under sea-water for two months and comparing its calorific value before and after immersion. He found that the loss in heating value was less than one per cent. In his further experiments he made a practical test of fresh coal and coals known to have been submerged various lengthy periods of time by using them in a locomotive hauling a known load a certain distance under similar conditions. His first sample was the best Monmouthshire coal procurable, the second sample had been under water three years , the third had been submerged ten years, the fourth had been recovered by mud-men outside of the mouth of the River Usk. This latter was driftage from the wrecks in the Bristol Channel, and had probably been under water considerably longer than ten years; this sample he called "river coal". As a result of these tests the order of value in steam raising and actual working results, in which these coals came out in the tests, was: 1. The "river coal"; 2. Coal that had been under water ten years; 3. Fresh coal; 4. Coal that had been under water three years. Comparing values with the fresh or test coal, the "river" coal was 4 per cent. better, and that which had been under water ten years 1.8 per cent. That which had been under water three years had lost 1.6 per cent. of working power. The high value of the older "river" coal, he says, may probably be accounted for by the fact that in travelling through the mud and sand that gave it its rounded form, the harder and better kernels, as it were, had been pre-

served, and the looser textured, less valuable outside portions were worn away. As a result of his experiments Mr. Macaulay concludes that steam coal loses very little of its power by submersion under water for the length of time that it would be reasonably kept in naval store, and that as it is so important to naval vessels to gain the benefit of their full working power, and so much of this is due directly to the coal, the subaqueous storage of coal is advisable in place of the present methods of storing with access to air, by which so high a percentage of working power is lost.

Summation of Researches.

Judging from these opinions of practical engineers and scientists, the present methods of coal storage, without doubt often result in much loss from fires of spontaneous origin, and more or less loss by a deterioration in fuel value of the coal itself. The leading factors entering into the cause of these losses have been pointed out as being: (1) the kind of coal as to its volatile combustible content; (2) the presence of occluded inflammable gases in the coal both before and after mining; (3) the presence of pyrites or other sulphur compounds; (4) the size of the coal; (5) the presence of moisture; (6) the temperature; and (7) the accessibility of oxygen to the coal.

From the evidence at hand there seems to be very little doubt but that the coals of the lignite, bituminous and semi-bituminous character with their relatively high amounts of volatile combustible matter have a much greater tendency to weather than the anthracites where the volatile matter is low. There is considerable

evidence that methane and other less inflammable gases formed during the decomposition of vegetable matter which produces the coal are contained in the crevices of the coal as it lies in the earth and ooze out both during and after mining. This loss of inflammable gaseous matter often results in mine explosions, and its continuance after storage may result in an explosion and if not the value of the coal as a fuel is decreased by its escape.

Opinions differ as to just what part sulphur compounds, the most important of which is pyrites, play in the deterioration of coal. Some assign the leading part in cases of spontaneous ignition to pyrites, while others think that its action in this connection is of only minor importance and that absorbed oxygen has most to do with this phenomenon. Observations upon the effect of the air upon pyrites, however, seem to have pretty generally established the notion that pyritic oxidation tends to raise the temperature of the coal as well as to increase the tendency of the coal to break up, and that this oxidizing action is quite appreciably increased by the presence of moisture.

That slack is much more liable to spontaneous ignition and the deteriorating influence of weathering agents, seems to be the general opinion. Having more surface, the finer particles absorb oxygen much more rapidly and this rapidity of absorption causes an increase in temperature which in turn produces better conditions for absorption and chemical action between the carbon, hydrogen and pyrites or the coal and the absorbed oxygen. It would seem to me that the finer coal would hold the moisture longer, resulting in a greater use being made of its catalytic qualities.

Some think that the only part moisture plays in the deterioration of coal are materially assisting pyritic oxidation and mechanically breaking up the coal by falling on it or by alternate freezing and thawing in the crevices of the coal, thus exposing more surface to weathering agents. There are many, however, who believe that aside from increasing the oxidation of pyrites, water has to do with other chemical activities, which result in the decomposition of the coal. These believe that oxidation of the carbon and hydrogen of the coal is hastened by the catalytic action of the water present. This latter view seems to be well supported by the fact that moisture has, in many instances, greatly increased the deterioration of practically non-pyritic coal.

That an increase of temperature has much to do with increasing the activity of the other deteriorating agents is the general belief. This rise of temperature whether coming from outside sources or physical or chemical action within the coal tends to accelerate the absorption of oxygen and thereby increases the oxidation going on and also evaporates the gases which may be yet occluded in the coal. Thus heat assists in decreasing the fuel value of the coal as well as decreases its liability to ignition. That the exclusion of oxygen from coal will decrease its loss in heating value is a growing belief.

From the evidence at hand it seems, therefore, that opinions differ as to the degree to which weathering features in the handling of our coal supplies and also as to just what are the leading factors in coal deterioration. From the diversity of opinions it would seem that much yet remains to be investigated in regard to the weathering of coal.

Investigations.

The experimental work was undertaken in order to determine whether any loss of calorific value does actually take place when coal is exposed under various conditions and to learn anything which might shed light upon any feature of the coal storage problem.

Ten representative coals from different mines of the State of Illinois were selected and samples taken from the cars or bins of dealers and consumers as soon as possible after the coal was mined. The sampling was done by the author and in case of the nut and slack coal was accomplished by using a shovel and digging down into the coal of the car or pit, and in this manner collecting quite a quantity of coal from all parts of the heap which was afterwards quartered and a sample of from 15 to 20 pounds taken for storage. In the case of lump coal, a heap of two or three bushels of lumps were collected from all parts of the bin or car and the lumps broken up into one and two inch pieces and then quartered and sampled.

The samples were stored in containing vessels in each case and four kinds of storage were adopted; viz.: (1) placing in an outdoor atmosphere and wetting samples frequently; (2) storing near the tunnel of the University Heating Plant where the observed temperature range was from 85° to 120° Fahr. and frequently wetting samples; (3) storing without wetting near the boilers of the University Heating Plant where the observed temperature range was from 85° to 120° Fahr.; and (4) storing under water at the laboratory temperature of about 70° Fahr.

A small sample of each coal was reserved and analyzed and samples were taken from the quantities placed in storage after five months, seven months and nine months respectively. The analyses of all samples included the determination of ash, moisture, volatile matter, fixed carbon, total sulphur, B. T. U. per pound of pure coal. All volatile matter was determined by heating one gram of coal in a porcelain crucible in the Hempel furnace for seven minutes with a twenty centimeter non-luminous flame. Total sulphur was determined from the combustion residues of the calorimeter after a calorific determination, and was by the gravimetric method of weighing as barium sulphate. The British thermal units per pound of coal were determined by use of the Parr electrically ignited calorimeter and in each case the proper corrections were made for calorimeter and accelerator factors and radiation. Ash and moisture determinations were made in the usual manner and other results shown in the tables gotten by the necessary computation.

The tables from I to X inclusive give results of the various analyses of these ten samples.

In order to determine the effect of exposure upon ground samples, four freshly ground samples that had passed 100-mesh were exposed in the laboratory and wetted occasionally. A portion of each was analyzed after 45 days, 90 days, and 135 days respectively. The analyses of these ground samples are given in tables XI to XIV inclusive.

TABLE I. Analyses of a car sample of an Oakwood, Vermilion County, coal; mined day previous to sampling. Nut coal passing between bars 1-1/2" apart. No slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	15.17	11.60	11.37	14.55	7.52	13.87
Moisture	11.00	6.22	9.42	11.15	6.81	10.86
Ash & Moisture Free						
Volatile Matter	42.82	43.01	45.78	43.99	41.73	44.02
Fixed Carbon	57.18	56.99	54.22	56.01	58.27	55.98
Total Sulphur	2.14	2.20	2.05	1.98	1.66	1.72
B.T.U. per pound	14759	14228	13924	13321	14532	14581
Loss in B.T.U.		531	835	1438	227	178
Loss in per cent.		3.6	5.6	9.5	1.5	1.2

TABLE II. Analysis of a car sample of an ~~Oakwood~~ Killsville coal, mined day previous to sampling; all coals through bars 1-1/2" apart; considerable slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
	air dry	5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	16.88	13.86	20.60	23.22	9.51	9.82
Moisture	6.29	6.05	8.26	10.04	6.95	7.32
Ash & Moisture Free						
Volatile Matter	43.28	42.66	46.34	43.43	43.56	43.02
Fixed Carbon	56.72	57.34	53.66	56.57	56.44	56.98
Total Sulphur	2.01	1.90	1.78	2.12	2.31	2.07
B.T.U. per pound	14412	14082	14151	14007	14423	14400
Loss in B.T.U.		330	261	405	00	12
Loss in per cent.		2.3	1.8	2.3	00	0.1

	85°-120° Fahr. - Dry			85°-120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	13.98	16.57	17.80	16.49	17.24	16.48
Moisture	1.69	1.61	3.15	5.43	3.38	4.18
Ash & Moisture Free						
Volatile Matter	38.43	41.18	40.16	42.62	39.02	41.99
Fixed Carbon	61.57	58.82	59.84	57.38	60.98	58.01
Total Sulphur	2.30	2.24	2.02	2.02	1.78	1.83
B.T.U. per pound	13799	13867	13907	14008	13949	14029
Loss in B.T.U.	613	545	495	404	463	383
Loss in per cent.	4.2	3.8	3.4	2.8	3.2	2.7

TABLE III. Analyses of car sample of Pawnee, Vermilion Co. washed pea; mined day previous to sampling.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	9.65	10.33	10.97	11.94	7.03	8.07
Moisture	10.42	7.03	10.36	12.82	7.44	8.08
Ash & Moisture Free						
Volatile Matter	40.54	39.39	43.58	41.67	41.94	42.61
Fixed Carbon	59.46	60.61	56.42	58.33	59.06	57.39
Total Sulphur	2.48	1.99	1.48	1.80	1.59	1.63
B.T.U. per pound	14391	14371	14375	14041	14191	14202
Loss in B.T.U.		20	16	350	200	89
Loss in per cent.		.2	.1	2.4	1.4	.6

	85°-120° Fahr.- Dry			85°-120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	8.55	20.15	13.04	9.63	8.88	8.36
Moisture	2.80	1.80	3.12	7.41	3.55	3.89
Ash & Moisture Free						
Volatile Matter	38.91	39.58	38.26	39.12	42.34	40.26
Fixed Carbon	61.09	60.42	61.74	60.88	57.66	59.74
Total Sulphur	2.33	2.29	1.97	1.82	1.47	1.91
B.T.U. per pound	13983	13832	14097	14145	13645	13679
Loss in B.T.U.	408	459	294	246	746	712
Loss in per cent.	2.8	3.2	2	1.7	5.2	5

TABLE IV. Analyses of bin samples of Pana, Christian County coal; mined three weeks before sampling. Nut and some slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	7.95	10.85	9.43	8.09	6.94	6.75
Moisture	8.32	5.20	6.70	8.84	6.86	8.01
Ash & Moisture Free						
Volatile Matter	48.29	48.87	47.92	45.44	46.31	45.82
Fixed Carbon	51.71	51.13	52.08	54.56	53.69	54.18
Total Sulphur	4.33	3.79	3.92	4.12	3.57	3.68
B.T.U. per pound	14228	14191	14161	14072	14102	14128
Loss in B.T.U.		37	126	156	67	100
Loss in per cent.		..2	.9	1.1	.5	.7

	85°-120° Fahr. - Dry			85° - 120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	8.19	10.08	8.90	6.69	8.28	6.82
Moisture	2.10	3.27	2.87	3.50	3.35	7.92
Ash & Moisture Free						
Volatile Matter	43.92	44.62	44.32	45.62	47.94	43.94
Fixed Carbon	56.08	55.38	55.68	54.38	52.06	56.06
Total Sulphur	4.41	4.32	4.30	3.85	4.00	4.27
B.T.U. per pound	13925	13948	13982	13978	13533	13389
Loss in B.T.U.	303	280	246	250	695	839
Loss in per cent.	2.1	1.9	1.7	1.7	4.9	5.8

TABLE V. Analyses of Riverton, Sangamon County bin samples; mined four weeks before sampling. Nut and slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	17.61	15.44	8.94	14.22	14.65	13.72
Moisture	8.85	5.16	7.28	11.00	7.40	6.89
Ash & Moisture Free						
Volatile Matter	47.34	44.18	43.81	45.09	46.29	45.62
Fixed Carbon_ _ _ _	52.66	55.82	56.19	54.91	53.71	54.38
Total Sulphur	3.47	3.49	3.78	2.93	3.51	3.23
B.T.U. per pound	15139	14303	14028	13983	14780	14831
Loss in B. T. U.		836	1111	1156	359	308
Loss in per cent.		5.5	7.3	7.4	2.3	2.2

	85° - 120° Fahr.- Dry			85° - 120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	9.61	11.16	10.59	18.09	14.65	16.23
Moisture	2.12	2.12	3.06	2.50	3.48	3.42
Ash & Moisture Free						
Volatile Matter	43.04	43.29	42.75	45.02	45.19	41.67
Fixed Carbon_ _ _ _	56.96	56.81	57.25	54.98	54.81	58.33
Total Sulphur	3.67	3.77	3.21	3.42	3.16	3.60
B.T.U. per pound	13678	13557	13479	13920	13841	13869
Loss in B.T.U.	1461	1582	1660	1219	1298	1270
Loss in per cent.	9.6	10.4	10.5	8.00	8.6	8.1

TABLE VI. Analyses of Carterville, Williamson County car sample; mined five days before sampling. Nut and slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	11.51	8.86	7.87	8.02	7.56	8.21
Moisture	5.12	4.57	7.50	7.00	4.16	5.12
Ash & Moisture Free						
Volatile Matter	36.57	35.58	40.79	34.31	38.88	37.03
Fixed Carbon_ _ _ _	63.43	64.42	59.21	65.69	61.12	62.97
Total Sulphur	1.10	1.27	1.17	1.20	1.19	.98
B.T.U. per pound	15248	15191	14476	14559	14765	14812
Loss in B.T.U.		57	772	689	483	436
Loss in per cent.		.3	5.00	4.5	3.2	3.1

	85° - 120° Fahr.- Dry			85° - 120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	6.16	11.15	9.41	7.20	8.83	8.70
Moisture	1.65	1.76	2.58	1.65	2.78	3.26
Ash & Moisture Free						
Volatile Matter	35.32	35.15	34.83	37.74	38.18	36.79
Fixed Carbon_ _ _ _	64.68	64.85	65.17	62.26	61.82	63.21
Total Sulphur	1.23	1.54	1.31	.93	1.73	1.13
B.T.U. per pound	13657	13709	14222	13749	13911	14155
Loss in B.T.U	1591	1539	1026	1499	1337	1093
Loss in per cent.	10.4	10.1	6.7	9.00	8.7	6.8

TABLE VII. Analyses of Majestic, Perry County bin sample; mined three weeks before sampling. Nut and slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	9.16	9.76	7.23	9.34	7.49	7.65
Moisture	6.17	5.70	6.34	7.26	5.77	6.21
Ash & Moisture Free						
Volatile Matter	37.97	38.82	38.37	40.27	41.72	40.21
Fixed Carbon	62.03	61.18	61.63	57.73	58.28	59.79
Total Sulphur	2.17	2.11	1.87	2.27	1.52	1.83
B.T.U. per pound	14457	14315	14235	13711	14299	14327
Loss in B.T.U.		142	222	746	158	30
Loss in per cent.		.9	1.5	5.1	1.1	.2

	85° - 120° Fahr. - Dry			85° - 120° Fahr. Wetted Often		
	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
Coal as Received						
Ash	10.19	9.30	8.88	8.75	10.96	8.29
Moisture	1.83	2.22	3.08	3.58	2.67	3.62
Ash & Moisture Free						
Volatile Matter	38.22	39.09	36.25	39.16	40.95	34.97
Fixed Carbon	61.78	60.91	63.75	60.84	59.05	65.03
Total Sulphur	2.35	2.10	2.43	1.91	1.52	2.23
B.T.U. per pound	13974	13912	14141	13607	13407	14320
Loss in B.T.U.	483	545	316	850	1050	137
Loss in per cent.	3.3	3.8	2.2	5.8	7.2	.9

TABLE VIII. Analyses of Pana Lump bin samples; mined three weeks before sampling. Lumps broken to 2 and 1 inch pieces. No slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	7.07	8.32	8.63	8.72	8.72	8.17
Moisture	9.02	6.10	7.21	8.05	8.13	9.12
Ash & Moisture Free						
Volatile Matter	43.66	44.06	42.88	43.21	43.12	42.86
Fixed Carbon	56.34	55.94	57.12	56.79	56.88	57.14
Total Sulphur	4.43	4.01	3.82	4.27	4.51	4.01
B.T.U. per pound	14682	14650	14402	14521	14602	14583
Loss in B.T.U.		32	280	161	80	99
Loss in per cent.		.2	1.6	1.1	.5	.7

	85° - 120° Fahr.- Dry		
	5 mos.	7 mos.	9 mos.
Coal as Received			
Ash	9.29	9.03	8.23
Moisture	3.03	2.15	2.62
Ash & Moisture Free			
Volatile Matter	42.31	44.72	45.07
Fixed Carbon	57.69	55.28	54.93
Total Sulphur	4.35	4.40	4.61
B.T.U. per pound	14025	14075	14127
Loss in B.T.U.	657	607	555
Loss in per cent.	4.1	4.1	3.9

TABLE IX. Analyses of a Springfield, Sangamon County, bin sample; mined four weeks before sampling. Lumps broken to 2 and 1 inch pieces. No slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	10.94	11.39	11.55	10.61	10.98	10.81
Moisture	6.55	4.23	5.28	6.17	7.35	8.46
Ash & Moisture Free						
Volatile Matter	41.81	40.50	39.69	38.72	41.53	38.67
Fixed Carbon	58.19	59.50	60.31	61.28	58.47	61.33
Total Sulphur	3.49	2.97	2.81	3.27	3.29	2.98
B.T.U. per pound	14058	14103	13950	13910	14021	13982
Loss in B.T.U.		000	108	148	37	76
Loss in per cent.		000	.7	1	.2	.5

	85° - 120° Fahr. - Dry		
	5 mos.	7 mos.	9 mos.
Coal as Received			
Ash	12.17	11.02	11.07
Moisture	1.87	2.03	3.15
Ash & Moisture Free			
Volatile Matter	38.72	38.19	38.81
Fixed Carbon	61.28	61.81	61.19
Total Sulphur	3.35	3.32	3.42
B.T.U. per pound	13897	13831	13867
Loss in B.T.U.	161	227	191
Loss in per cent.	1.1	1.6	1.3

TABLE X. Analyses of Du Quoin, Perry County, car sample; mined one week before sampling. Lumps broken to 2 and 1 inch pieces. No slack.

	Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
		5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
Coal as Received						
Ash	13.74	14.23	14.50	13.82	11.33	12.81
Moisture	7.65	8.11	7.83	8.15	10.33	9.25
Ash & Moisture Free						
Volatile Matter	46.84	45.82	46.63	45.52	47.53	46.21
Fixed Carbon	53.16	54.18	53.37	54.48	52.47	53.79
Total Sulphur	1.30	1.21	1.11	1.32	1.41	1.17
B.T.U. per pound	14933	14125	14021	14087	14959	14903
Loss in B.T.U.		808	812	846	000	30
Loss in per cent.		5.4	5.4	5.5	000	0.2

	85° - 120° Fahr. - Dry		
	5 mos.	7 mos.	9 mos.
Coal as Received			
Ash	15.88	15.76	14.87
Moisture	1.06	1.23	2.76
Ash & Moisture Free			
Volatile Matter	46.00	47.75	45.65
Fixed Carbon	54.00	52.25	54.35
Total Sulphur	1.37	1.38	1.29
B.T.U. per pound	14301	14256	14327
Loss in B.T.U.	632	677	606
Loss in per cent.	4.2	4.5	4.1

TABLE XI. Analyses of Oakwood egg car sample; mined day before sampling, and ground to pass 100-mesh.

	Before Exposure	70° Fahr. Wetted Occasionally		
		45 Days	90 Days	135 Days
Coal as Received				
Ash	24.45	24.21	24.11	23.69
Moisture	4.62	2.54	2.78	3.36
Ash & Moisture Free				
Volatile Matter	47.97	47.61	47.63	48.01
Fixed Carbon	52.03	52.39	52.37	51.99
Total Sulphur	12.05	12.39	11.73	12.21
B.T.U. per pound	14287	13261	13304	13119
Loss in B.T.U.		1026	983	1168
Loss in per cent.		7.2	6.8	8.2

TABLE XII. Analyses of a Springfield bin sample; mined four weeks before sampling. Nut and slack; ground to pass 100-mesh.

	Before Exposure	70° Fahr. Wetted Occasionally		
		45 Days	90 Days	135 Days
Coal as Received				
Ash	11.47	12.30	12.24	11.07
Moisture	11.05	3.07	3.92	4.30
Ash & Moisture Free				
Volatile Matter	42.15	48.03	46.93	47.08
Fixed Carbon	57.85	51.97	53.07	52.92
Total Sulphur	6.79	6.63	5.82	5.95
B.T.U. per pound	13959	13852	13783	13354
Loss in B.T.U.		107	176	605
Loss in per cent.		.7	1.2	4.4

TABLE XIII. Analyses of a Pawnee washed pea car sample; mined day before sampling; ground to pass 100-mesh.

Coal as Received	Before Exposure	70° Fahr. Wetted Occasionally 45 Days	90 Days	135 Days
Ash	14.74	15.85	15.94	15.47
Moisture	9.50	2.51	2.50	3.42
Ash & Moisture Free				
Volatile Matter	43.20	44.01	43.92	43.70
Fixed Carbon	56.80	55.99	56.08	56.30
Total Sulphur	1.21	1.39	1.04	1.20
B.T.U. per pound	14278	13865	14176	13991
Loss in B.T.U.		413	102	287
Loss in per cent.		2.8	.7	2

TABLE XIV. Analyses of Oakwood car sample; mined day before sampling. Nut, no slack, ground to pass 100-mesh.

Coal as Received	Before Ex Exposure	70° Fahr. Wetted Occasionally 45 Days	90 Days	135 Days
Ash	15.17	10.31	16.99	16.78
Moisture	11.00	3.04	2.80	3.04
Ash & Moisture Free				
Volatile Matter	42.82	41.92	42.73	42.81
Fixed Carbon	57.18	58.08	57.27	57.19
Total Sulphur	1.07	1.24	.93	1.15
B.T.U. per pound	14759	14487	14582	14162
Loss in B.T.U.		272	177	397
Loss in per cent.		1.8	1.2	2.7

TABLE XV. This table shows the value in B.T.U. per pound of pure coal of the coals whose analyses, at different stages, are given in tables 1 to 10 inclusive, together with their respective losses.

Table Number		Before Exposure	Outdoor Exposure Wetted Often			Submerged at 70° Fahr.	
			5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
I.	B. T. U.	14759	14228	13424	13321	14532	14581
	Loss		531	1335	1438	227	178
II.	B. T. U.	14412	14082	14151	14007	14423	14400
	Loss		330	261	405	000	12
III.	B. T. U.	14391	14371	14191	14041	14375	14097
	Loss		20	200	350	16	294
IV.	B. T. U.	14228	14191	14161	14072	14102	14128
	Loss		37	67	156	126	100
V.	B. T. U.	15139	14303	14028	13983	14780	14831
	Loss		836	1111	1156	359	308
VI.	B. T. U.	15248	15191	14476	14559	14765	14812
	Loss		57	779	689	483	436
VII.	B. T. U.	14457	14315	14235	13711	14299	14327
	Loss		142	222	746	158	30
VIII.	B. T. U.	14682	14650	14402	14521	14602	14583
	Loss		32	280	161	80	99
IX.	B. T. U.	14058	14103	13950	13910	14021	13982
	Loss		000	108	148	37	76
X	B. T. U.	14933	14125	14021	14087	14959	14903
	Loss		808	812	846	000	30

TABLE XV. (Continued)

Table Number		85° - 120° Fahr. - Dry			85° - 120° Fahr. Wetted Often		
		5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.
I.	B.T.U.						
	Loss						
II.	B.T.U.	13799	13867	13907	14008	13949	14029
	Loss	613	545	495	404	463	383
III.	B.T.U.	13983	13832	14202	14145	13645	13679
	Loss	408	459	89	246	746	712
IV.	B.T.U.	13925	13948	13982	13978	13533	13389
	Loss	303	280	246	250	695	839
V.	B.T.U.	13678	13557	13479	13920	13841	13869
	Loss	1461	1582	1660	1219	1298	1270
VI.	B.T.U.	13657	13701	14222	13749	13911	14155
	Loss	1591	1547	1026	1499	1337	1093
VII.	B.T.U.	13974	13912	14141	13607	13407	13320
	Loss	483	545	316	850	1050	1137
VIII.	B.T.U.	14025	14075	14127			
	Loss	657	607	555			
IX.	B.T.U.	13897	13831	13867			
	Loss	161	227	191			
X.	B.T.U.	14301	14256	14327			
	Loss	632	677	606			

TABLE XVI. This table shows the value in B.T.U. per pound of pure coal of the finely ground samples whose analyses, at different stages, are given in tables 11 to 14 inclusive, together with their respective losses.

Table Number		Before Exposure	70° Fahr. Wetted Occasionally		
			45 Days	90 Days	135 Days
XI.	B. T. U.	14287	13261	13304	13119
	Loss		1026	983	1168
XII.	B. T. U.	13959	13852	13783	13354
	Loss		107	176	605
XIII.	B. T. U.	14278	13865	14176	13991
	Loss		413	102	287
XIV.	B. T. U.	14759	14487	14582	14162
	Loss		272	177	397

Conclusions.

The results given in table XV indicate that there is more or less loss in British thermal units by practically every coal subjected to atmospheric exposure, this loss varying from nothing in a few cases of five months outdoor exposure to almost 1600 B.T.U. in a few cases of high temperature exposure.

It is also shown that there is a greater calorific loss during the high temperature exposures than the out door exposure, the least high temperature loss being 161 B.T.U. and the greatest 1591 B.T.U., while the least loss on outdoor exposure is no B.T.U. and the greatest 1111 B.T.U.

In five out of ten cases the loss in B.T.U. after seven months submersion is so near zero as to be within the limits of error, while the greatest loss is 483 B.T.U.

In but six out of twenty-five possible instances do the analyses show that there is an appreciable decrease in B.T.U. between the five and seven month determinations. These are I, V, and VI during outdoor exposure and III, IV and VII at from 85 to 120 Fahr. and often wetted.

The following table gives the average losses in B.T.U. of the samples under the varying conditions of exposure.

Outdoor Exposure Wetted Often			85°-120° Fahr.-Dry			85°-120° Fahr. Wetted Often			Submerged at 70° Fahr.	
5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.	5 mos.	7 mos.	9 mos.	7 mos.	9 mos.
278	513	572	701	696	576	745	930	739	159	156

The few instances of decrease after five months are so marked that an increase of average loss is shown in the outdoor and high temperature wet conditions. The relation between the loss on submersion and the other losses is well shown in this table.

A comparatively high average loss of 454 B.T.U. after 45 days which remains about the same after 90 days of exposure is shown in table XVI for the finely ground samples. That the loss may be affected by the amount of sulphur present is shown by the fact that number XI with 12 per cent. sulphur has a maximum loss of 1026 B.T.U., which is over twice the loss of any of the other samples. The fact, however, that number XII with a sulphur content of 7 per cent. shows a smaller loss than either numbers XIII and XIV, whose sulphur content is but about one percent, argues against this conclusion.

In appearance those coals subjected to outdoor exposure were dulled and slightly more friable than when placed there. Those in a dry condition at a high temperature were of about the same appearance but considerably more friable, while those at a high temperature were very much dulled in appearance and quite brittle. The submerged still retained their fresh luster, were apparently no more brittle than when placed there, and in every way resembled freshly mined samples.

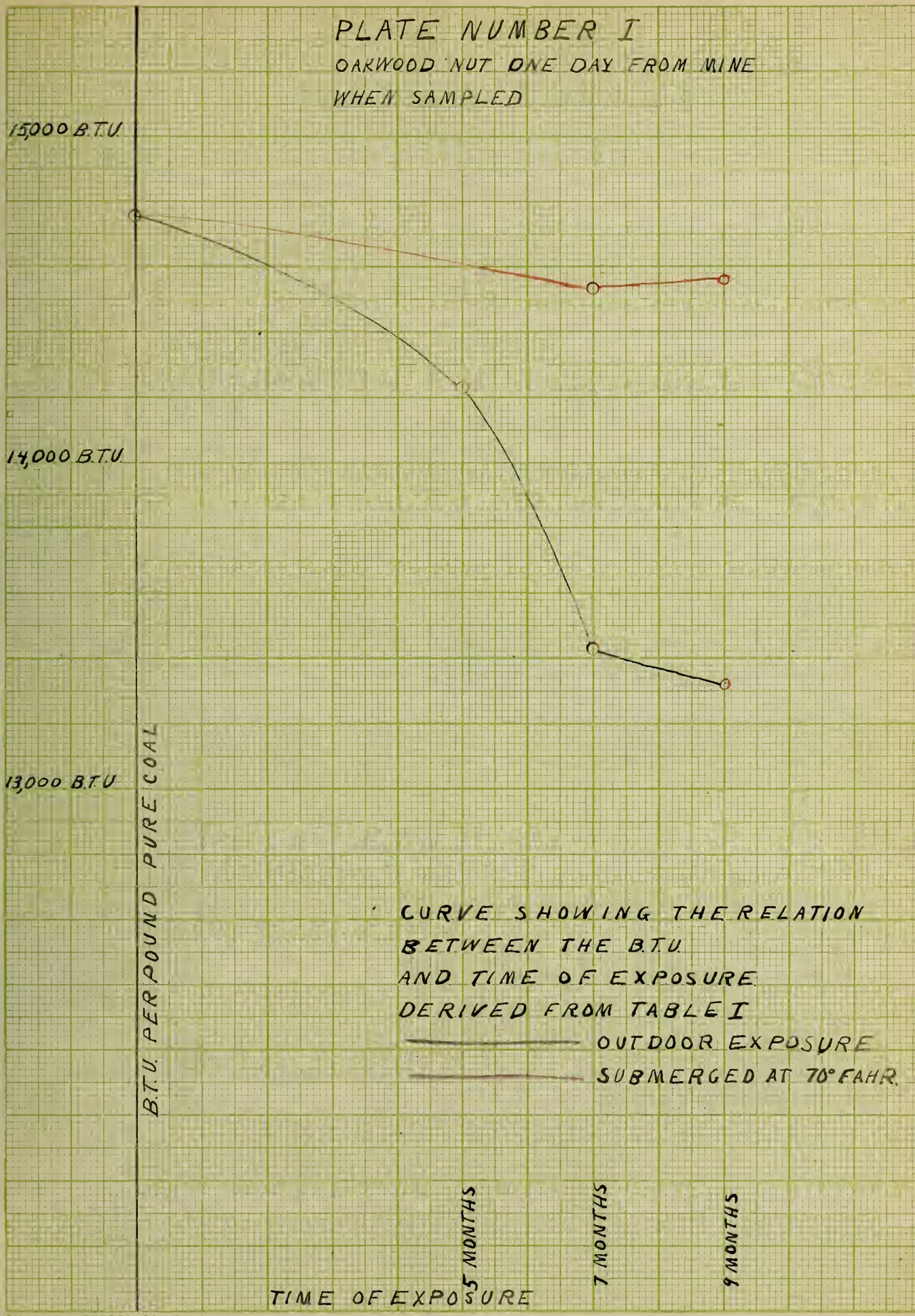
There are several attending conditions which may have more or less influenced upon the results of these investigations. Coming as they do from different parts of the state and the variation in time between time of mining and their first analysis would evidently mean a difference in the nature of the coals as well as a possible previous greater loss in the case of some coals than others. The size of the respective samples varied and the relative amount of slack in those containing it was necessarily different. A uniform sample was scarcely obtainable in the latter cases of sampling when the exposed portions had been decreased in quantity while the size of the pieces remained the same.

These variations in nature and history of the various samples make the causes of different losses in heating value of the several samples difficult to define. A few conditions of more or less significance may, however, be gotten from the result of the experiments. Coal number IV relatively high in sulphur and volatile matter and of about the same age as numbers VI and VII which are relatively low in these constituents shows less loss in calorific value, thus indicating that there may be other things which feature

in the deterioration besides the content of sulphur and volatile matter. That the presence of slack increases the deterioration may be concluded when the relatively large losses of the slack containing coals V and VI are compared with the losses of coals VIII and IX with no slack. This is also shown by the relatively high loss in heating value of the finely ground sample. Much remains for future investigation in order to determine just what takes place within the coal during the weathering process, and to establish the causes for the varying degrees of susceptibility of various coals to weathering agencies.

PLATE NUMBER I

OAKWOOD NUT ONE DAY FROM MINE WHEN SAMPLED



CURVE SHOWING THE RELATION BETWEEN THE B.T.U. AND TIME OF EXPOSURE DERIVED FROM TABLE I

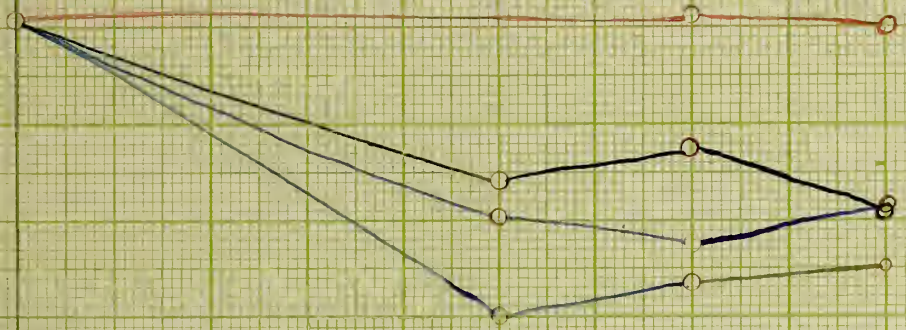
OUTDOOR EXPOSURE

SUBMERGED AT 70° FAHR.

EUGENE DIETZGEN CO., CHICAGO.

PLATE NUMBER II.

OAKWOOD NUT AND SLACK ONE DAY FROM MINE WHEN SAMPLED



15,000 B.T.U.

14,000 B.T.U.

13,000 B.T.U.

B.T.U. PER POUND PURE COAL

CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE. DERIVED FROM TABLE II.

——— OUTDOOR EXPOSURE

——— AT 85°-120° FAHR. DRY

——— AT 85°-120° FAHR. WETTED OFTEN

SUBMERGED AT 70° FAHR.

5 MONTHS

7 MONTHS

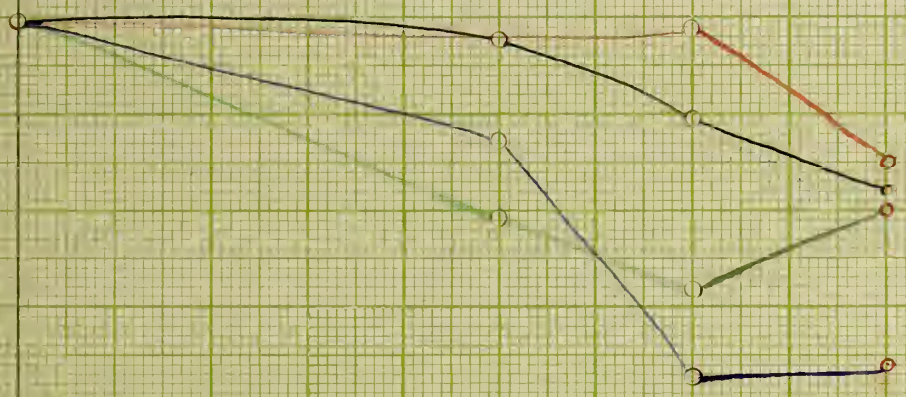
9 MONTHS

TIME OF EXPOSURE

EUGENE DIETZGEN CO., CHICAGO.

PLATE NUMBER III

PAWNEE WASHED PEA ONEIDAY
FROM MINE WHEN SAMPLED



15,000 B.T.U.

14,000 B.T.U.

13,000 B.T.U.

B.T.U. PER POUND PURE COAL

CURVES SHOWING THE RELATION
BETWEEN THE B.T.U.
AND THE TIME OF EXPOSURE
DERIVED FROM TABLE III

——— OUTDOOR EXPOSURE
AT 85°-120° FAHR DRY
AT 85°-120° FAHR WETTED OFTEN
SUBMERGED AT 70° FAHR.

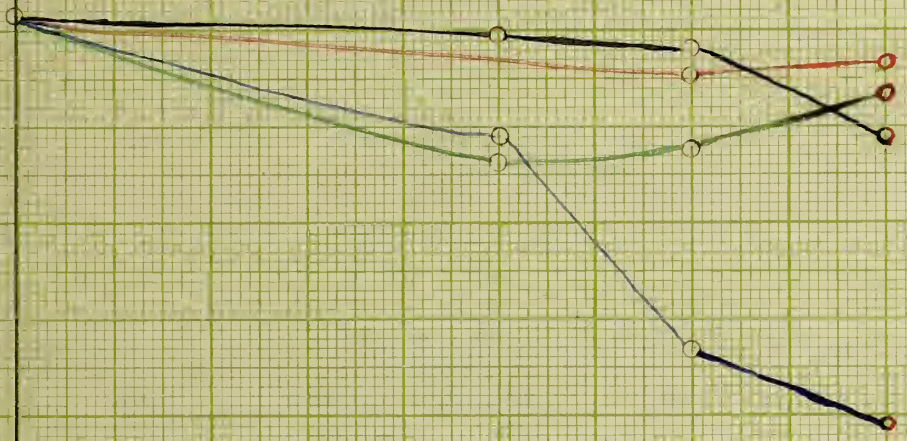
5 MONTHS
7 MONTHS
9 MONTHS

TIME OF EXPOSURE

EUGENE DIETZGEN CO., CHICAGO.

PLATE IV

PANA NUT AND SLACK 3 WEEKS FROM MINE WHEN SAMPLED



15,000 B.T.U.

14,000 B.T.U.

13,000 B.T.U.

B.T.U. PER POUND PURE COAL

CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE DERIVED FROM TABLE IV

OUTDOOR EXPOSURE

AT 85°-120° FAHR. DRY

AT 85-120° FAHR. WETTED OFTEN

SUBMERGED AT 70° FAHR.

5 MONTHS

7 MONTHS

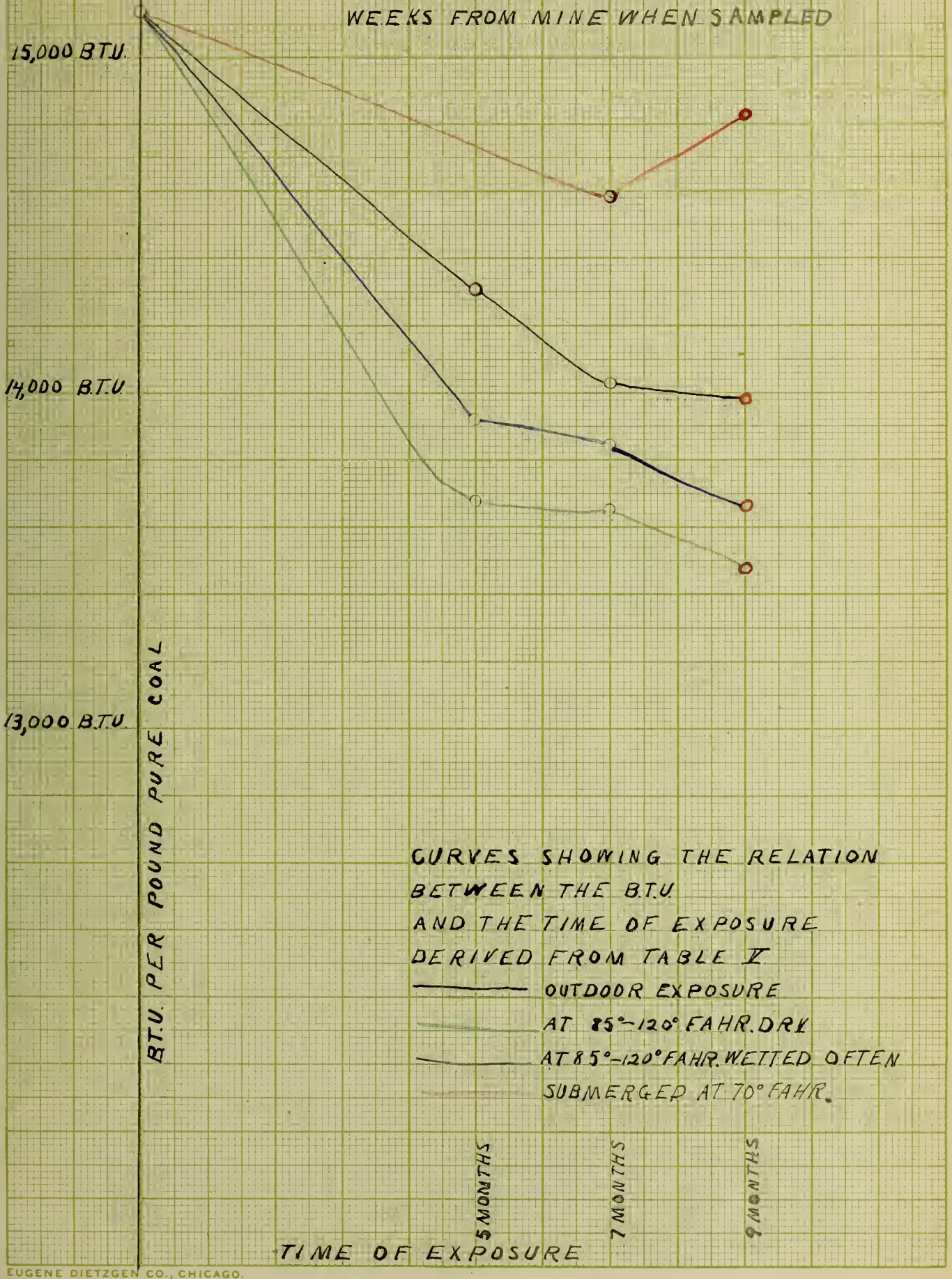
9 MONTHS

TIME OF EXPOSURE

EUGENE DIETZGEN CO., CHICAGO.

PLATE V

RIVERTON NUT AND SLACK FOUR WEEKS FROM MINE WHEN SAMPLED



CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE DERIVED FROM TABLE V.

——— OUTDOOR EXPOSURE

AT 85°–120° FAHR. DRY

——— AT 85°–120° FAHR. WETTED OFTEN

SUBMERGED AT 70° FAHR.

EUGENE DIETZGEN CO., CHICAGO.

PLATE VI

15,000 B.T.U.

14,000 B.T.U.

13,000 B.T.U.

B.T.U. PER POUND PURE COAL

CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE DERIVED FROM TABLE VI

OUTDOOR EXPOSURE

AT 85°–120° FAHR DRY

AT 85°–120° FAHR WETTED OFTEN

SUBMERGED AT 70° FAHR

5 MONTHS

7 MONTHS

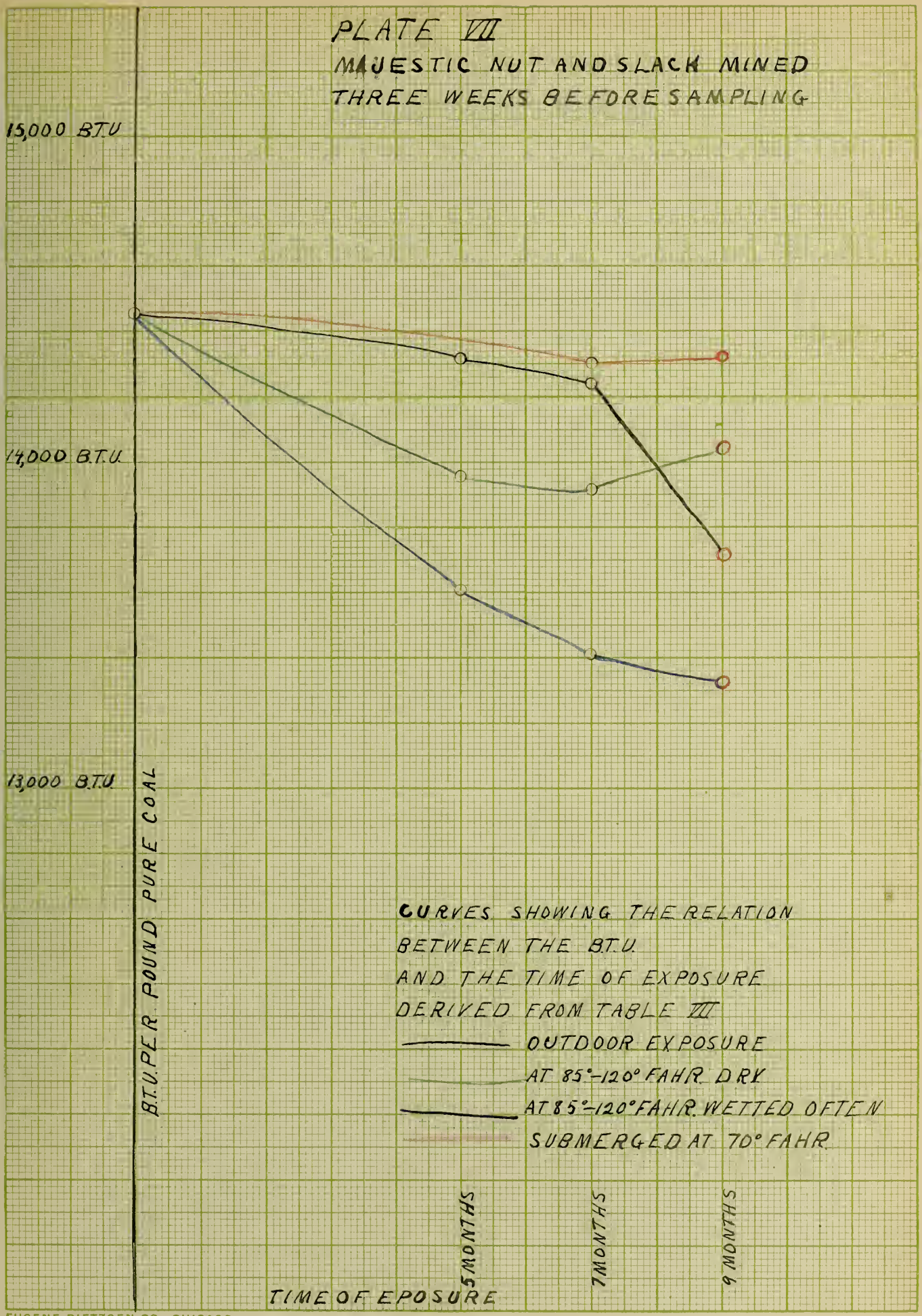
9 MONTHS

TIME OF EXPOSURE

EUGENE DIETZGEN CO., CHICAGO.

PLATE VII

MAJESTIC NUT AND SLACK MINED THREE WEEKS BEFORE SAMPLING



CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE DERIVED FROM TABLE VII

——— OUTDOOR EXPOSURE

AT 85°–120° FAHR. DRY

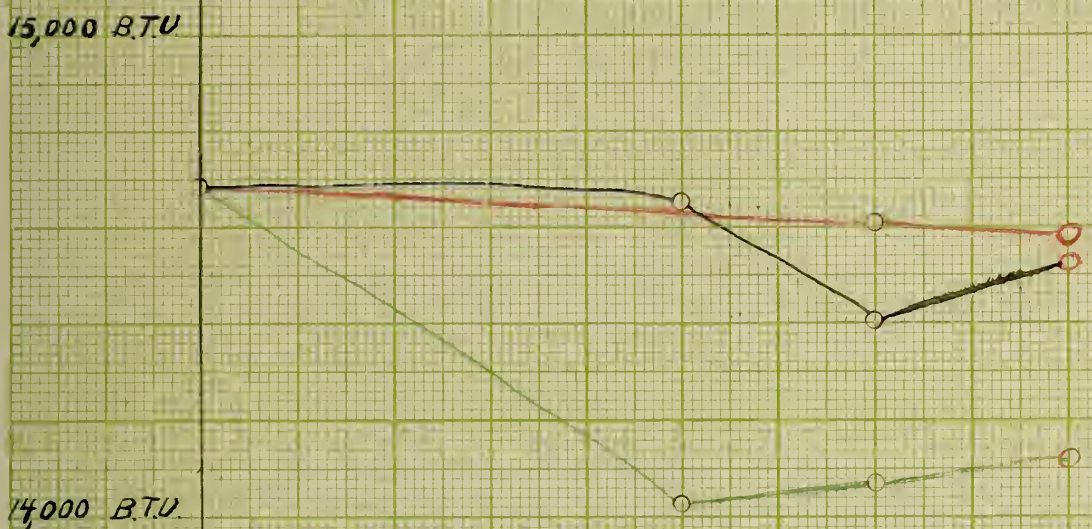
——— AT 85°–120° FAHR. WETTED OFTEN

SUBMERGED AT 70° FAHR.

EUGENE DIETZGEN CO., CHICAGO.

PLATE VIII

PANA LUMP BROKEN TO NUT SIZES
MINED THREE WEEKS BEFORE SAMPLING



CURVES SHOWING THE RELATION
BETWEEN THE B.T.U.
AND THE TIME OF EXPOSURE
DERIVED FROM TABLE VIII

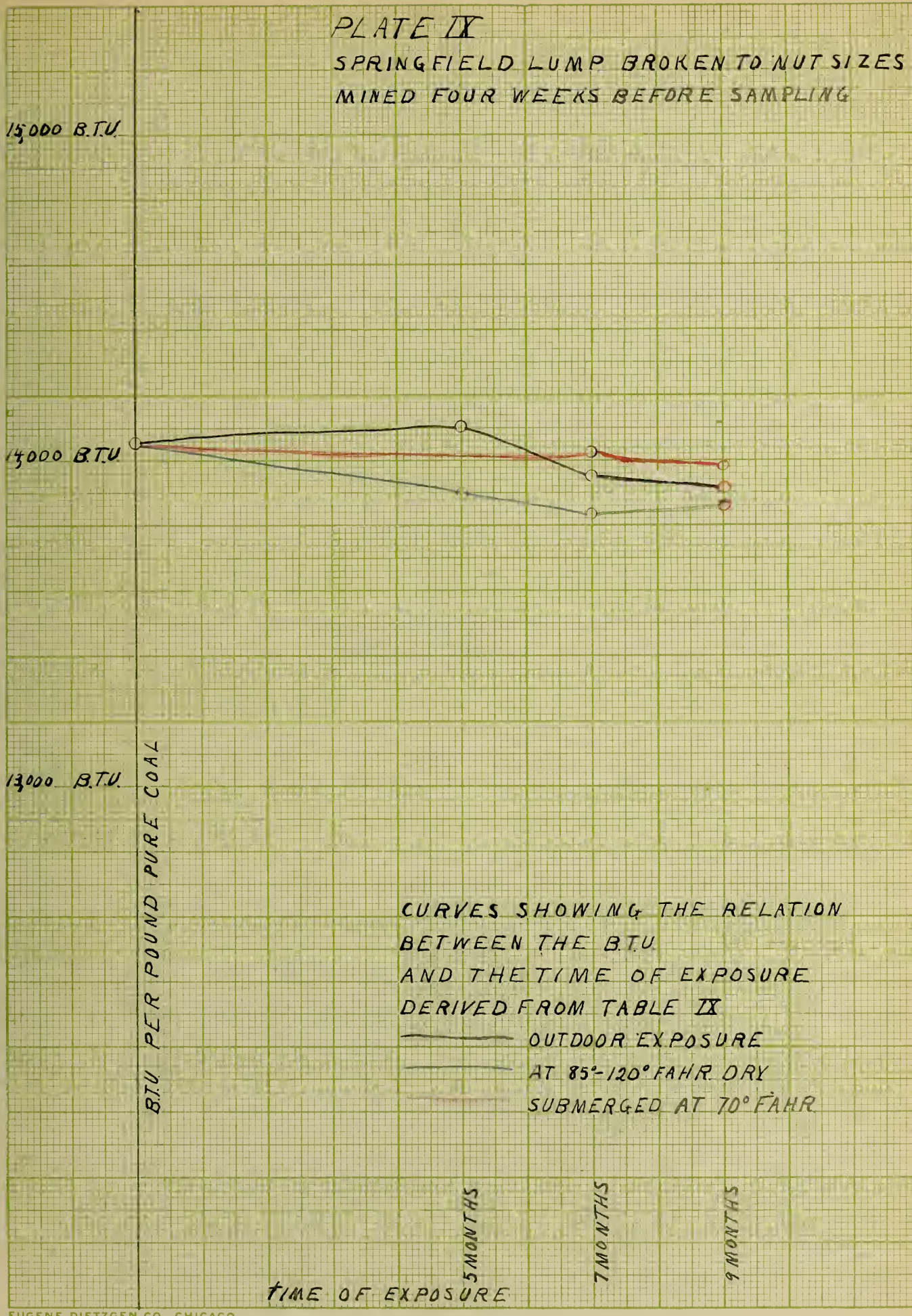
——— OUTDOOR EXPOSURE
AT 85°-120° FAHR. DRY

——— SUBMERGED AT 70° FAHR.

EUGENE DIETZGEN CO., CHICAGO

PLATE IX

SPRINGFIELD LUMP BROKEN TO NUT SIZES
MINED FOUR WEEKS BEFORE SAMPLING



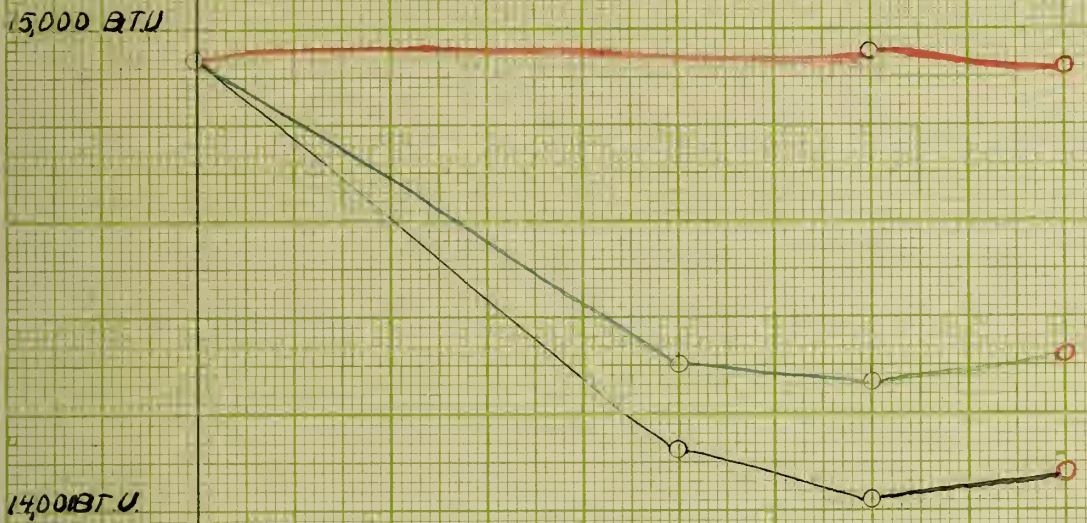
CURVES SHOWING THE RELATION
BETWEEN THE B.T.U.
AND THE TIME OF EXPOSURE
DERIVED FROM TABLE IX

——— OUTDOOR EXPOSURE
——— AT 85°-120° FAHR. DRY
——— SUBMERGED AT 70° FAHR.

EUGENE DIETZGEN CO., CHICAGO.

PLATE X

DUQUOIN LUMP BROKEN TO NUT SIZES
MINED ONE WEEK BEFORE SAMPLING



CURVES SHOWING THE RELATION
BETWEEN THE B.T.U.
AND THE TIME OF EXPOSURE
DERIVED FROM TABLE X

OUTDOOR EXPOSURE
AT 85°-120° FAHR. DRY
SUBMERGED AT 70° FAHR.

5 MONTHS
7 MONTHS
9 MONTHS

TIME OF EXPOSURE

EUGENE DIETZGEN CO., CHICAGO.

PLATE XI

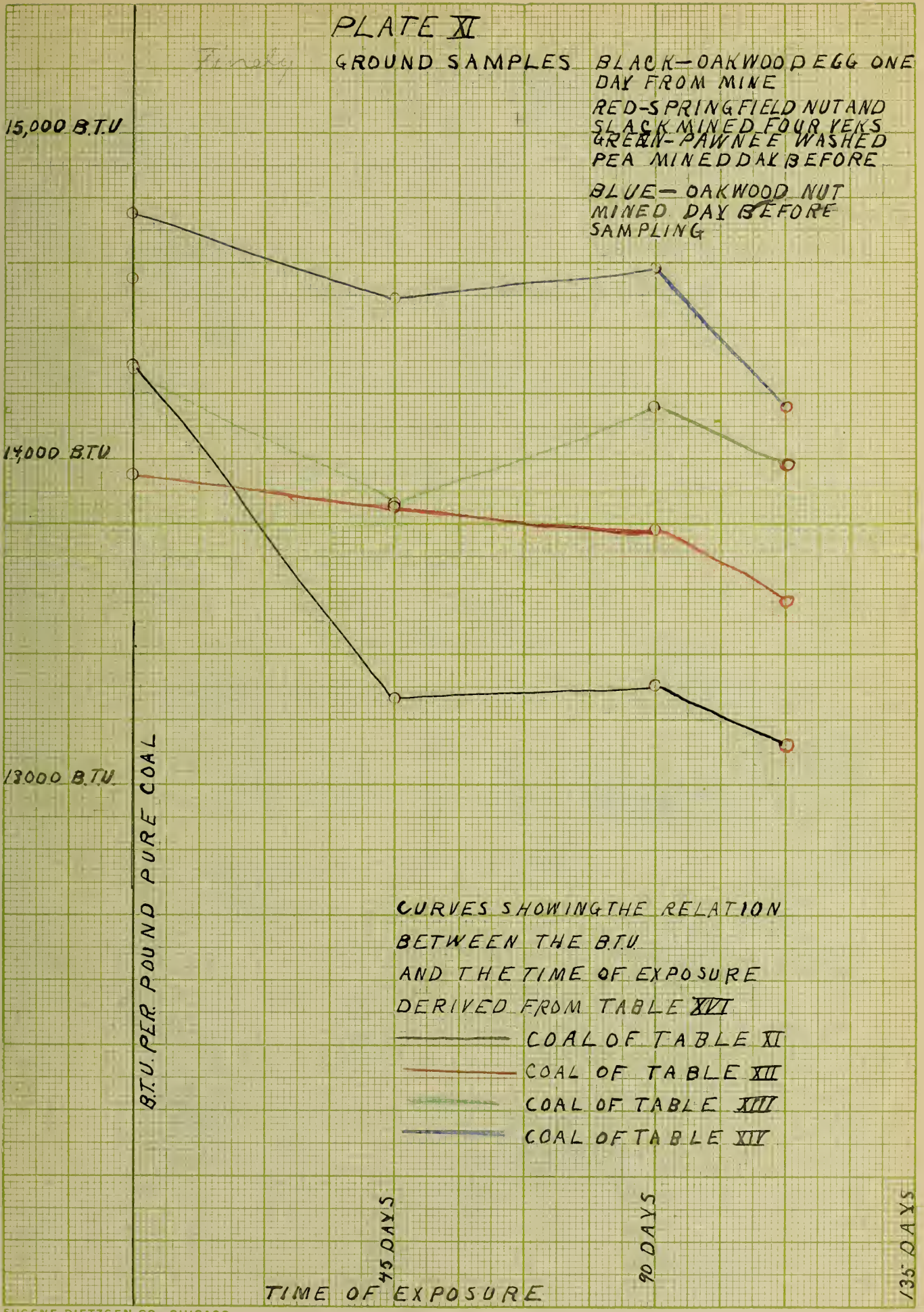
GROUND SAMPLES

BLACK—OAKWOOD EGG ONE DAY FROM MINE

RED-SPRINGFIELD NUT AND SLACK MINED FOUR WEEKS

GREEN-PAWNEE WASHED PEA MINED DAY BEFORE

BLUE—OAKWOOD NUT MINED DAY BEFORE SAMPLING



CURVES SHOWING THE RELATION BETWEEN THE B.T.U. AND THE TIME OF EXPOSURE DERIVED FROM TABLE XVI

COAL OF TABLE XI

COAL OF TABLE XII

COAL OF TABLE XIII

COAL OF TABLE XIV

EUGENE DIETZGEN CO., CHICAGO.

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